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(71) Applicant: KONINKLIJKE PTT NEDERLAND N.V. [NL/NL]; P.O. Box 95321, NL-2509 CH The Hague (NL).

(72) Inventors: WISSENBURGH, Jelle; le Sweelinckstraat 16, NL-2517 GC The Hague (NL). BREHLER, Johannes; Prins Frederiklaan 348, NL-2263 HS Leidschendam (NL). MULLER, Frank; Meerkoetlaan 24, NL-2623 NJ Delft (NL). DE LANGE, Martin, Klaas; Kersengaarde 188, NL-2272 NN Voorburg (NL). FEIKEN, Albertus; Praam 135, NL-1186 TD Amstelveen (NL). VAN DE PAVERT, Hendricus, Johannes, Wilhelmus, Maria; Klipper 53, NL-3904 SL Veenendaal (NL).

(74) Agent: BEITSMA, Gerhard, Romano; Koninklijke PTT Nederland N.V., P.O. Box 95321, NL-2509 CH The Hague (NL).

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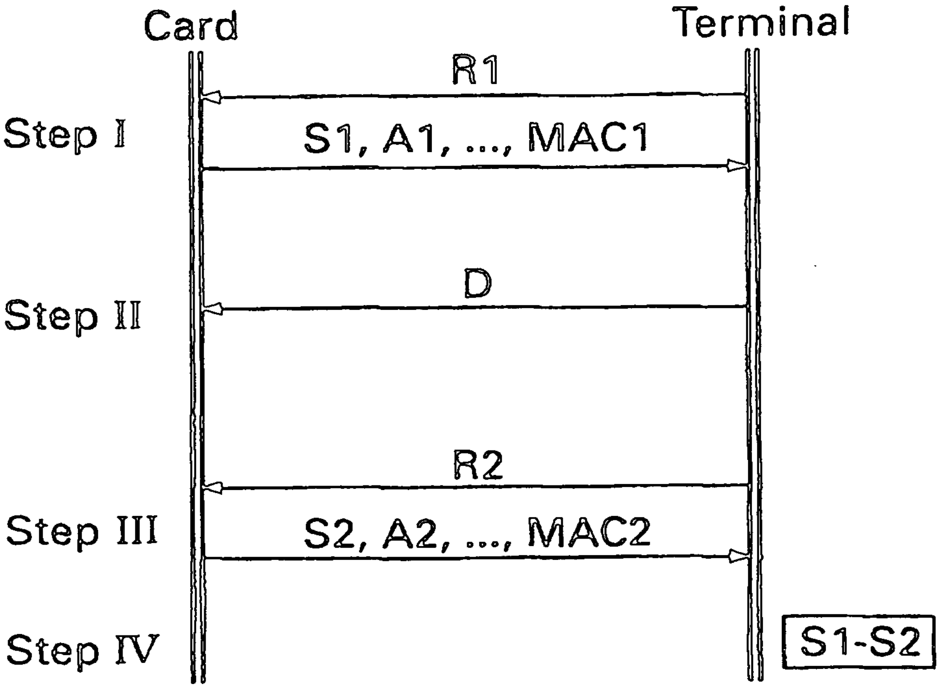
(54) Title: METHOD FOR PROTECTEDLY DEBITING AN ELECTRONIC PAYMENT MEANS

(57) Abstract

The invention relates to a method for protected transactions involving a so-called smart card (11) and a terminal (12), such as a cash register. In order to prevent the smart card from simultaneously carrying out transactions with several terminals, the invention provides an authentication value (A) which is used in the data exchange between the smart card (11) and the terminal (12) to uniquely identify subsequent steps (e.g. I, III) of the transaction.



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Method for protectedly debiting an electronic payment means.

BACKGROUND OF THE INVENTION

The invention relates to a method for debiting an electronic payment means, such as an electronic payment card provided with an integrated circuit ("chip card"). In particular, though not exclusively, the invention relates to a method for protectedly debiting prepaid electronic payment cards ("prepaid cards") as these are applied, e.g., for telephone booths. In the present text, the term payment means will be used irrespective of the form or the type of the specific payment means. A payment means may therefore be formed by, e.g., a chargeable payment card or a non-card-shaped electronic payment means.

In recent years, electronic payment means are being applied ever more frequently, not only for paying for the use of public telephone sets, but also for many other payment purposes. Since such a payment means generally comprises a (credit) balance which represents a monetary value, it is necessary to have the exchange of data between such a payment means and a payment station (such as a telephone set designed for electronic payment or an electronic cash register) run according to a protected method (payment protocol). Here, it should be ensured, e.g., that an amount (monetary value or number of calculation units) debited to the payment means correspond to an amount (monetary value or calculation units) credited elsewhere: the amount paid by a customer should correspond to the amount to be received by a supplier. The credited amount may be stored, e.g., in a protected module present in the payment station.

Prior Art payment methods, as disclosed in e.g. European Patent Application EP 0,637,004, comprise: a first step, in which the balance of the payment means is retrieved by the payment station; a second step, in which the balance of the payment means is lowered (debiting the payment means); and a third step, in which the balance of the payment means is retrieved again. From the difference between the balances of the first and third steps the debited amount, and therewith the amount to be credited in the payment station, may be determined. The second step may be repeated several times, possibly in combination with the third step.

In order to prevent fraud, in the event of such a method the first step makes use of a random number which is generated by the payment station and transferred to the payment means, e.g., as part of a code with which the balance is retrieved. On the basis of said random number, the payment means as a first response generates an authentication code which may comprise an (e.g., cryptographic) processed form of, inter alia, the random number and the balance. By using a different random number for each transaction, it is prevented that a transaction may be imitated through replay. In addition, in the third step use is made of a second random number, which is also generated by the payment station and transferred to the payment means. On the basis of the second random number, the payment means as a second response generates a second, new authentication code which may comprise a processed form of, inter alia, the second random number and the new balance. On the basis of the difference of the two balances transferred, the payment station (or a protected module of the payment station, as the case may be) may determine with which amount the balance of the payment station should be credited.

Said known method is basically very resistant to fraud as long as a payment means communicates with one payment station (or protected module). The drawback of the known method, however, lies in the fact that the first and second authentication codes are independent. If a second or third payment station (or protected module) communicates with the payment means, it is possible, due to said independence, to separate the first step from the second and third steps. As a result, an apparently complete transaction may be achieved without the payment means in question being debited by the same amount as the amount by which the payment stations (or protected modules) in their entirety are credited. It will be understood that such is undesirable.

US Patent US 5,495,098 and corresponding European Patent Application EP 0,621,570 disclose a method in which the identity of the security module of the payment station is used to ensure that a data exchange takes place between the card and one terminal only. The protection of the data exchange between the security module, the station and the card is relatively complicated and requires extensive cryptographic calculations.

Other Prior Art methods are disclosed in e.g. European Patent Applications EP 0,223,213 and EP 0,570,924, but these documents do not offer a solution to the above-mentioned problems.

SUMMARY OF THE INVENTION

It is an object of the invention to eliminate the above and other drawbacks of the Prior Art, and to provide a method which offers an even greater degree of protection of debiting transactions. In particular, it is an object of the invention to provide a method which ensures that during a transaction there only takes place communication between the payment means and one payment station or protected module. More in particular, it is an object of the invention to provide a method which ensures that the amount by which the balance of a payment means is lowered during a transaction, corresponds to the amount by which the balance of only one payment station or protected module is increased.

Accordingly, the present invention provides a method of performing a transaction using payment means and a payment station, the method comprising the repeated execution of an interrogation step in which the payment station interrogates the payment means and receives payment means data in response, the payment means data comprising an authentication code produced by a predetermined process, a subsequent authentication code being linked to a preceding authentication code of the same transaction by an authentication value produced in both the payment means and the payment station. By linking the authentication codes by authentication values, it is possible to distinguish authentication codes of the initial transaction from authentication codes of an interfering transaction. Preferably, the authentication value is altered in each interrogation step, thus providing an improved security.

More specifically, the present invention provides a method of protectedly debiting an electronic payment means using a payment station, the method comprising:

- a first step, in which:
  - the payment station transfers a first random number to the payment means,
  - the payment means, in response to said first random number, transfers a first authentication code to the payment station, which first authentication code is determined on the basis of at least the first random number and a first authentication value, and

- the payment station checks the first authentication code;
- an optional second step, in which:
  - the payment station transfers a debiting command to the payment means and the balance of the payment means is lowered on the basis of the debiting command; and
- a third step, in which:
  - the payment station transfers a second random number to the payment means,
  - the payment means, in response to said second random number, transfers a second authentication code to the payment station, with the second authentication code being determined on the basis of at least the second random number and a second authentication value, the second authentication value being derived from the first authentication value, and
  - the payment station derives the second authentication value from the first authentication value and checks the second authentication code.

By forming the authentication codes on the basis of, inter alia, mutually related authentication values, there is offered the possibility to check whether the second authentication code (in the third step) is related to the first authentication code (in the first step). By now generating a new authentication value each time an authentication code must be determined, there is offered the possibility of distinguishing consecutive authentication codes, and therewith to distinguish authentication codes associated with different transactions. If, each time the first or third step is carried out, there is generated a uniq::e authentication value, it may be unequivocally determined which second authentication code is related to which first one. Therewith it may also be determined whether, within a transaction, a second authentication code has already been issued.

The authentication values are basically autonomously generated by the payment means. There preferably is not possible any influencing from outside, such in order to prevent fraud. The authentication values may be generated in various ways, e.g., by a random generator or by a counter.

The first and second authentication values of a transaction may be related by them having, e.g., the same value, or by them having mutually dependent values, such as consecutive values of a counter. Also, the first authentication value may be a random number, and the second authentication value may be formed from the first one by adding a certain number thereto. Basically, each pair of authentication values should be related in such a manner that this is capable of being unequivocally checked.

It is a further object of the invention to provide an electronic payment means and a payment station in which the method is applied.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be explained in greater detail below by reference to the Figures.

Fig. 1 schematically shows a payment system in which the invention may be applied.

Fig. 2 schematically shows a method in which the invention is applied.

Fig. 3 schematically shows the producing of an authentication code as used in the method of Fig. 2.

Fig. 4 schematically shows the integrated circuit of a payment means with which the invention may be applied.

DESCRIPTION OF PREFERRED EMBODIMENTS

The system 10 for electronic payment schematically shown in Fig. 1, by way of example comprises an electronic payment means, such as a so-called chip card or smart card 11, a payment station 12, a first payment institution 13, and a second payment institution 14. The payment station (terminal) 12 is shown in Fig. 1 as a cash register, but may also comprise, e.g., a (public) telephone set. The payment institutions 13 and 14, both denoted as bank in Fig. 1, may not only be banks but also further institutions having at their disposal means (computers) for settling payments. In practice, the payment institutions 13 and 14 may form one payment institution. In the example shown, the payment means 11 comprises a substrate and an integrated circuit having contacts 15, which circuit is designed for processing (payment) transactions. The payment means may also comprise an electronic wallet.

Between the payment means 11 and the payment station 12 there takes place, during a transaction, an exchange of payment data PD1. The payment means 11 is associated with the payment institution 13, while the payment station 12 is associated with the payment institution 14. Between the payment institutions 13 and 14 there takes place, after a transaction, a settlement by exchanging payment data PD2, which is derived from the payment data PD1. During a transaction there basically does not take place communication between the payment station 12 and the payment institution 14 in question (so-called off-line system). Transactions must therefore occur under controlled conditions to ensure that there can take place no abuse of the system. Such an abuse may be, e.g., increasing a balance of the payment means 11 which is not matched by a balance change of a counterpart account at the payment institution 13.

The diagram of Fig. 2 shows the exchange of data between (the integrated circuit of) a payment means denoted as "Card" (11 in Fig. 1) and (the protected module of) a payment station denoted as "Terminal" (12 in Fig. 1), with consecutive occurrences being shown one below the other.

In the first step, denoted by I, the terminal (payment station) produces a first random number R1 and transfers this number to the card (payment means) (substep Ia). In practice, the random number R1 may be part of a code for retrieving an authentication code. According to the invention, the card and the terminal produce a first authentication value A1, e.g., by increasing a counter, activating a random number generator, or both. On the basis of the random number R1, the first authentication value A1 and other data, including the balance S1 of the payment means, the card produces an authentication code MAC1 = F(R1, A1, S1, ...), where F may be a cryptographic function known per se (substep Ib). The card data S1 and A1 as well as the authentication code MAC1 are transferred to the terminal (substep Ic). The terminal checks the authentication code on the basis of, inter alia, R1, S1 and A1 and, in the event of a positive check result, records the balance S1.

It should be noted that the transfer of the value A1 to the terminal is not essential to the present invention but serves to provide additional protection against fraud.

In the second step, denoted by II, the terminal produces a debiting command D, which comprises the amount (quantity) to be debited to the payment means. The debiting command D is transferred to the card, whereafter the balance S1 of the payment means is lowered by the quantity to be debited to S2. The second step may possibly be repeated several times.

In the third step, denoted by III, the terminal produces a second random number R2 and transfers this to the card (substep IIIa). The card generates a second authentication value A2. On the basis of the second random number R2, the second authentication value A2 and other data, including the new card balance S2, the card produces an authentication code MAC2 = F(R2, S2, ...), where F may be a cryptographic function known per se (substep IIIb). The card balance S2 and the authentication value A2 as well as the authentication code MAC1 are transferred to the terminal (substep IIIc). The third step may thus run fully analogously to the first step.

The terminal checks the second authentication code MAC2 received, e.g., by reproducing the authentication code and comparing the random number R2. The terminal also checks whether the received second authentication value A2 is equal to the corresponding value produced in the terminal. If the authentication values A2 are not equal, the transaction is terminated and the balance of the terminal is therefore not modified.

If the check of the authentication code MAC2 has a positive result, the terminal records the balance S2. Instead of reproducing the authentication codes MAC1 and MAC2, a deciphering may take place, e.g., by carrying out the inverse of the function F.

In a fourth step, denoted by IV, the difference of the balances S1 and S2 may be determined and recorded in the terminal. In this connection, such difference may either be stored separately or be added to an existing value (balance of the terminal) to be settled later. Said fourth step, just as possible following steps, is not essential for the invention. The steps shown in Fig. 2 may be preceded by an authentication or verification step; such, however, is not essential for the present invention either.

In the diagram, which has been discussed above, the random numbers R1 and R2 are different. The random numbers R1 and R2 may be identical (R1 = R2 = R), however, so that in step III it may also be checked whether in the authentication code MAC2 use is still being made of the same random number R (= R1).

It should be noted that strictly speaking the number R1, just as the number R2, need not be a random number: it serves for the unequivocal identification of the authentication code MAC1 as response to R1 ("challenge"). It is essential only that R1 be not recognisable to the card.

According to Prior Art methods, the authentication codes MAC1 and MAC2 are basically independent. This is to say that, if the random numbers R1 and R2 differ, there is no direct or indirect relationship between the codes MAC1 and MAC2. Due to this independence, there is basically no guarantee that the steps I and III are carried out between the same card and the same terminal.

According to the invention, however, when determining the second authentication code there is assumed an authentication value which is directly related to the authentication value used when determining the first authentication code. As a result, a relationship is established between the two authentication codes of the transaction in question. This relationship is preferably straightforward (e.g. A2 = A1 + 1) allowing a simple check.

If, e.g., the card receives a (first) random number R1' from a second terminal after the card has output a first authentication code MAC1 to a first terminal, the card will output an authentication code MAC2. If thereupon the first terminal, after outputting a debiting command, once again retrieves an authentication code, the card outputs a furthei authentication code MAC3 which is based, inter alia, on the further authentication value A3. The terminal will observe that the authentication codes MAC1 and MAC3 are not related, and will not be capable of using the balance value S3 which was included in the authentication code MAC3. Similarly, an authentication MAC4, which is retrieved by the second terminal, provides no valid authentication and therefore no valid balance value. In this manner, the transfer of modified balance values to several terminals is effectively prevented.

The authentication values are preferably formed by consecutive numbers, e.g., counter positions. It is also possible, however, to use a counter which is increased every other time (second time of generating an authentication value), so that each time two consecutive authentication values will be equal. It should be noted that the payment means may distinguish between the first and the third steps, but need not do so.

The said dependence of the authentication values in accordance with the invention ensures that all steps of the transaction in which the method according to the invention is applied, take place between the same payment means and the same terminal.

Fig. 3 schematically shows how an authentication code MAC ("Message Authentication Code"), such as MAC1 and MAC2 of Fig. 2, may be produced. Several parameters are input into a processing means 20 embodying a function denoted as "F". This function F may be a cryptographical function (such as e.g. the well-known DES function) or a so-called "hash" function, both of which are well known in the art. Alternatively, the function F is a relatively simple combinatorial function, in which case the processing means 20 may comprise a shift register with selective feedback. The parameters input into the processing means 20 and thus into the function F are in the example of Fig. 3: a random value R, a card balance S, an authentication value A, a key K and an initialization vector (start value) Q. The random value R corresponds with e.g. the values R1 and R2 transmitted to the card in step I and step III respectively. The card balance S corresponds with e.g. the balances S1 and S2 stored in the card. The key K may be a (secret) key which preferably is unique for a specific card or batch of cards. A key identifier may be exchanged with the terminal in an authentication or verification step prior to step I of Fig. 2.

The initialization vector Q, which initializes the process F, may always have a fixed value, e.g. zero. Alternatively, the vector Q depends on the residue (final state) of the function F after the previous step of the transaction. Preferably, the vector Q is reset when a new transaction is started.

The authentication value A is in the example shown generated by a counter 21. The counter is preferably increased at each interrogation step (e.g. step I and step III), i.e. at each step in which an authentication code (MAC) is produced in response to a random number (R). This results in a different authentication value A being used for each authentication code. As the increment (in this case +1, but +2 or +10 are also possible) is predetermined, the terminal is able to verify the authentication code. Preferably, the authentication value is also transmitted to and verified by the terminal. The counter 21 is reset when a new transaction is started.

In the example of Fig. 3, the authentication value A is produced by a counter. Alternatively, the counter 21 is replaced by a random number generator, which generates a new authentication value A for each interrogation step (e.g. steps I and III) of the transaction. In this case, the authentication value of the previous step should be used as initialization vector ("seed") of the random number generator in order to preserve the mutual dependence and reproducibility of the authentication values.

It will be understood that the scheme of Fig. 3 applies to both the card and the terminal. The terminal thus also produces authentication values A1, A2, ... and authentication codes MAC1, MAC2, ... and compares these with the corresponding authentication codes and values received from the card. A balance (e.g. S2) will only be accepted by the terminal if the produced and received authentication codes and values are equal.

On the basis of Fig. 4, it will be further explained how the method according to the invention may be applied to payment cards.

The diagram of Fig. 4 shows a circuit 100 having a control unit 101, a memory 102, and an input/output unit 103, which are mutually coupled. The control unit may be formed, e.g., by a microprocessor or a microcontroller. The memory 102 may comprise a RAM and/or ROM memory. The memory 102 preferably comprises a rewritable ROM memory (EEPROM).

According to the invention, the circuit 100 also comprises a supplementary memory 105 for storing authentication values. As shown in Fig. 4, said memory 105 may form a separate unit, but may also be part of the memory 102 and, e.g., be formed by a few memory positions of the memory 102. The memory 105 is preferably formed by a counter circuit. Alternatively, a separate counter circuit as shown in Fig. 3 may be used.

In a preferred embodiment, consecutive authentication values are formed by consecutive counter positions. A first authentication value A1, which is used to form the authentication code MAC1, corresponds to a position of the counter, as stored in the memory 105. After the second step (see also Fig. 2), the counter position is increased by one. The initial counter position may be basically random, but may also be reset to a predetermined value. e.g. zero.

Generating authentication values occurs autonomously, i.e., without (possible) influencing from outside. As a result, the resistance to fraud is further increased.

It will be understood that, instead of each time increasing the counter position by one, it may each time be decreased by one. Likewise, the counter position may each time be increased or decreased by more than one, e.g., by two or four. It is also possible to construct the circuit 100 in such a manner that the authentication value(s) are not modified within a transaction but only between transactions. In such a case, the payment station is of course arranged accordingly.

A payment station for the application of the invention comprises means (such as a card reader) for communicating with a payment means, means for carrying out authentications (such as a processor), and means for recording balance values (such as a semiconductor memory). The payment station is constructed in such a manner that an unsuccessful authentication makes it impossible for a new balance value to be recorded. The authentication according to the invention also comprises the authentication values. The steps of the method according to the invention may be laid down both in equipment (specific circuit, such as an ASIC) and in software (suitable program for a processor).

It will be understood by those skilled in the art that the invention is not limited to the embodiments shown, and that many modifications and amendments are possible without departing from the scope of the invention. Thus, the principle of the invention is described above on the basis of debiting a payment means, but said principle may also be applied to crediting payment means.

CLAIMS

1. Method of performing a transaction using payment means (11) and a payment station (12), the method comprising the repeated execution of an interrogation step (I; III) in which the payment station (12) interrogates the payment means (11) and receives payment means data (e.g. S1; S2) in response, the payment means data comprising an authentication code (MAC1; MAC2) produced by a predetermined process (F), a subsequent authentication code (e.g. MAC2) being linked to a preceding authentication code (MAC1) of the same transaction by an authentication value (e.g. A2) produced in both the payment means (11) and the payment station (12).

2. Method according to claim 1, wherein the authentication value (e.g. A1) is altered in each interrogation step (e.g. I).

3. Method according to claim 1 or 2, wherein the process (F) involves a key (K).

4. Method according to claim 1, 2 or 3, wherein the process (F) involves a random value (e.g. R2) produced by the payment station (12) and a payment means balance (e.g. S2).

5. Method of protectedly debiting an electronic payment means (11) using a payment station (12), the method comprising:

- a first step (I), in which:
  - the payment station (12) transfers a first random number (R1) to the payment means (11),
  - the payment means (11), in response to said first random number (R1), transfers a first authentication code (MAC1) to the payment station (12), which first authentication code (MAC1) is determined on the basis of at least the first random number (P1) and a first authentication value (A1), and
  - the payment station (12) checks the first authentication code (MAC1);
- an optional second step (II), in which:
  - the payment station (12) transfers a debiting command (D) to the payment means (11) and the balance (S1) of the payment means is lowered on the basis of the debiting command; and
- a third step (III), in which:
  - the payment station (12) transfers a second random number (R2) to the payment means (11),

- the payment means (11), in response to said second random number (R2), transfers a second authentication code (MAC2) to the payment station (12), with the second authentication code being determined on the basis of at least the second random number (R2) and a second authentication value (A2), the second authentication value (A2) being derived from the first authentication value (A1), and
- the payment station (12) derives the second authentication value (A2) from the first authentication value (A1) and checks the second authentication code (MAC2).

6. Method according to claim 5, wherein the first and second authentication values (A1, A2) are identical.

7. Method according to claim 5, wherein the first and second authentication values (A1, A2) comprise consecutive counter values.

8. Method according to claim 5, wherein an authentication value (e.g. A2) is each time formed on the basis of a random number (e.g. R2) and the previous authentication value (A1).

9. Method according to any of the preceding claims, wherein an authentication code (e.g. MAC2) is also determined on the basis of a key (K) and an identification code.

10. Method according to any of the preceding claims, wherein an authentication code (e.g. MAC1) is determined with the aid of a cryptographic function (F).

11. Method according to any of the preceding claims, in which in the first and third steps (I, III) the payment means (11) transfers a balance (e.g. S1) to the payment station (12).

12. Method according to any of the preceding claims, in which in the first and third steps (I, III) the payment means (11) transfers the current authentication value (e.g. A1) to the payment station (12).

13. Method according to any of the preceding claims, in which the third step (III) is carried out repeatedly.

14. Method according to any of the preceding claims, further comprising a fourth step (IV) wherein the difference (S1-S2) between the balances of the first and third steps is recorded in the payment station (12).

15. Method according to any of the preceding claims, wherein the first random number (R1) is equal to the second random number (R2).

16. Method according to any of the preceding claims, wherein the payment station (12) comprises a module for protectedly recording data.

17. Financial transaction, carried out by applying the method according to any of the preceding claims.

18. Electronic payment means (11), comprising an integrated circuit having processing means (101), a memory (102) and an input/output circuit (103), arranged for implementing the method according to any of the claims 1 to 16 inclusive.

19. Payment station (12), arranged for application of the method according to any of the claims 1 to 16 inclusive.

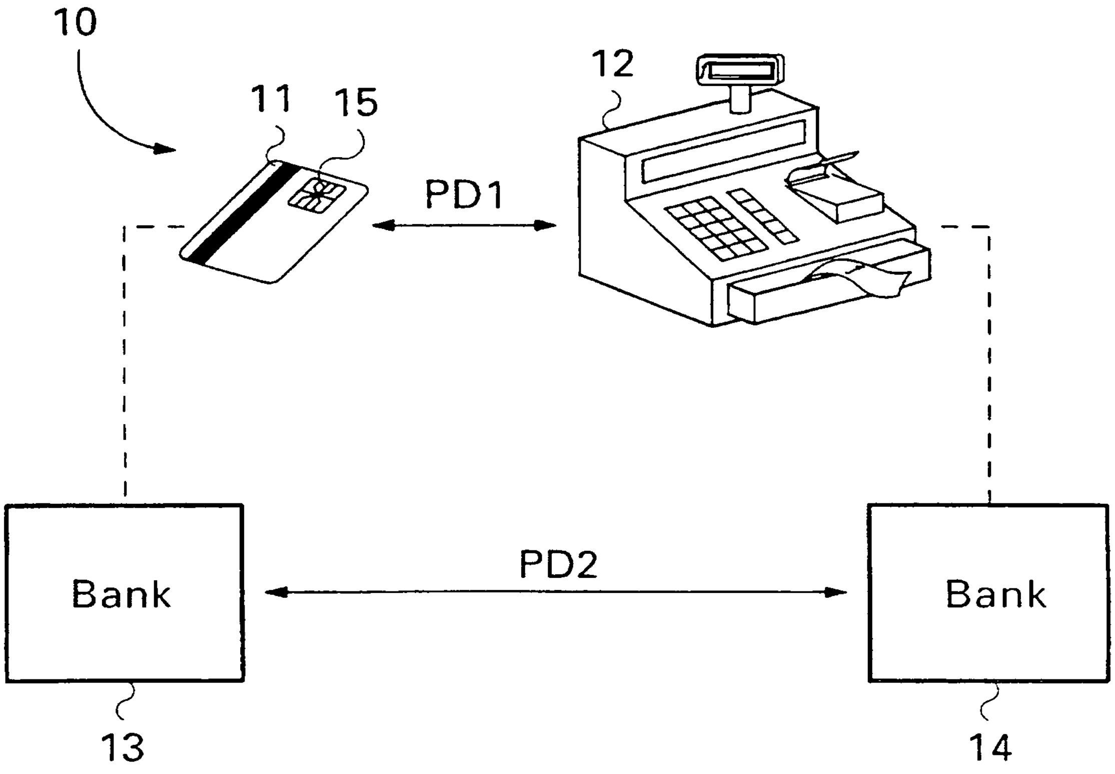

Fig. 1

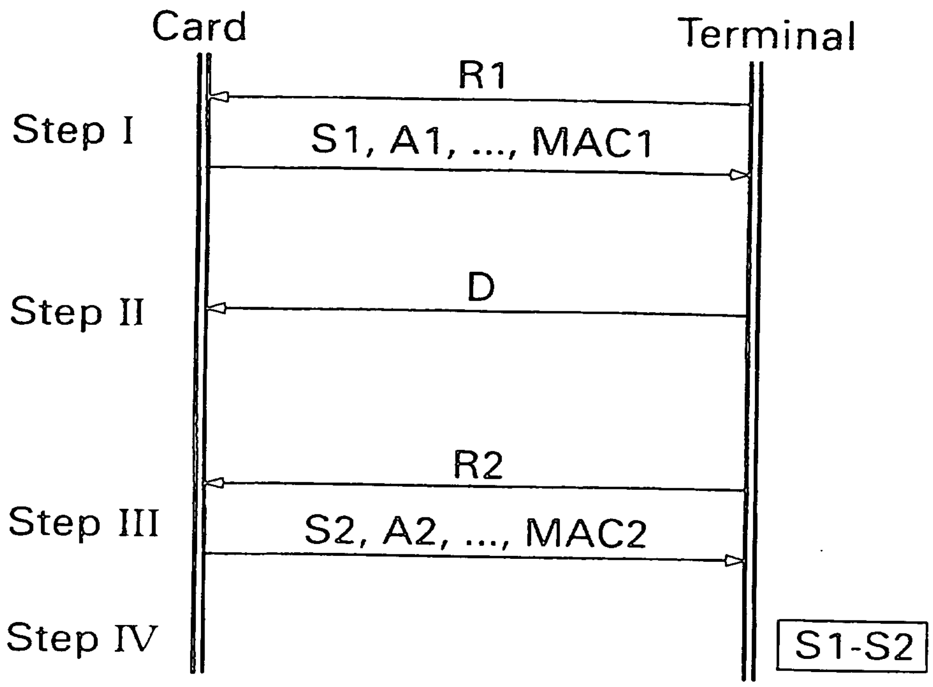
Card
Terminal
R1
Step I
S1, A1, ..., MAC1
D
Step II
R2
Step III
S2, A2, ..., MAC2
Step IV
S1-S2

Fig.2

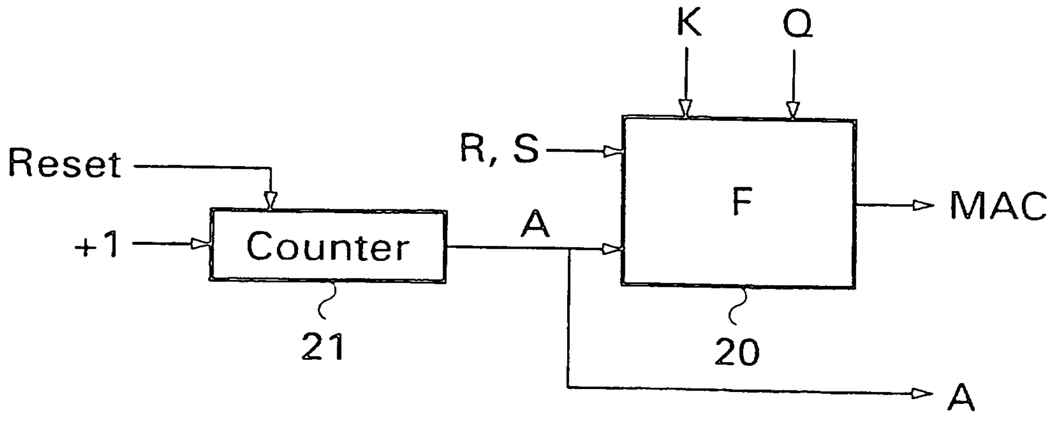
K
Q
Reset
R, S
F
MAC
+1
Counter
A
21
20
A

Fig.3

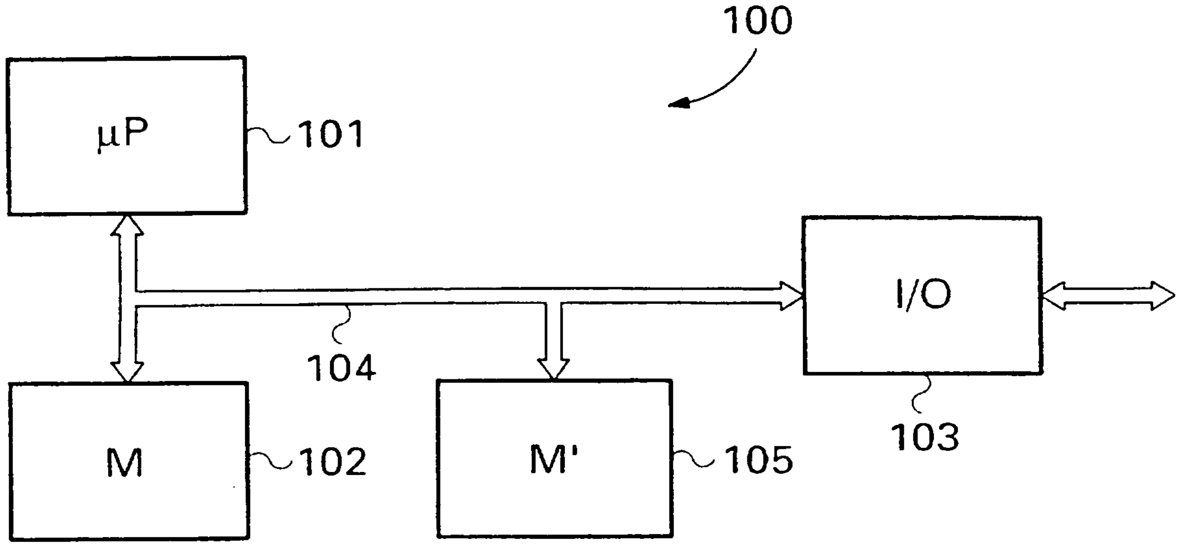

Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 96/05027

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G07F7/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G07F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 621 570 A (FRANCE TELECOM) 26 October 1994 cited in the application	1-5,7, 9-12,14, 17-19
A	see the whole document ---	16
Y	EP 0 570 924 A (SIEMENS) 24 November 1993 cited in the application see abstract; claims; figure ---	1-5,7, 9-12,14, 17-19
A	EP 0 409 701 A (ETAT FRANCAIS) 23 January 1991 -----	

□ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search 14 April 1997	Date of mailing of the international search report 02. 05. 97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Authorized officer David, J

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 96/05027

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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EP 0570924 A	24-11-93	EP 0570828 A	24-11-93
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		DE 69012692 T	19-01-95
		JP 3141487 A	17-06-91
		US 5128997 A	07-07-92

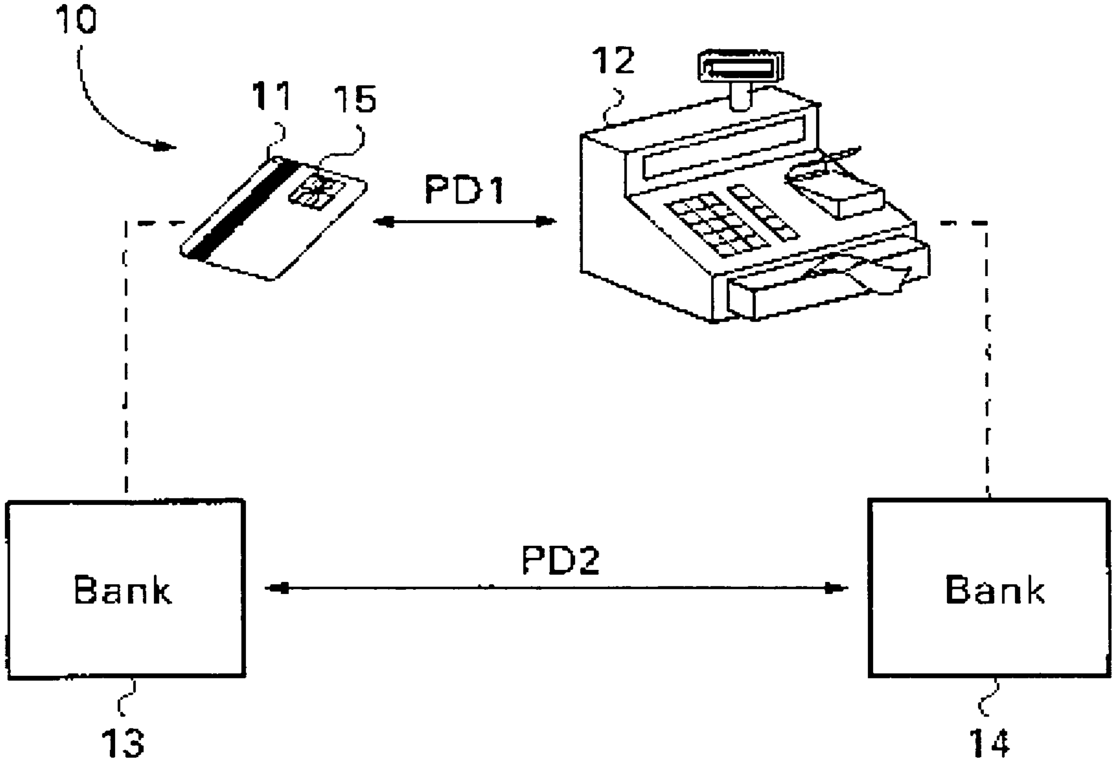

Fig. 1

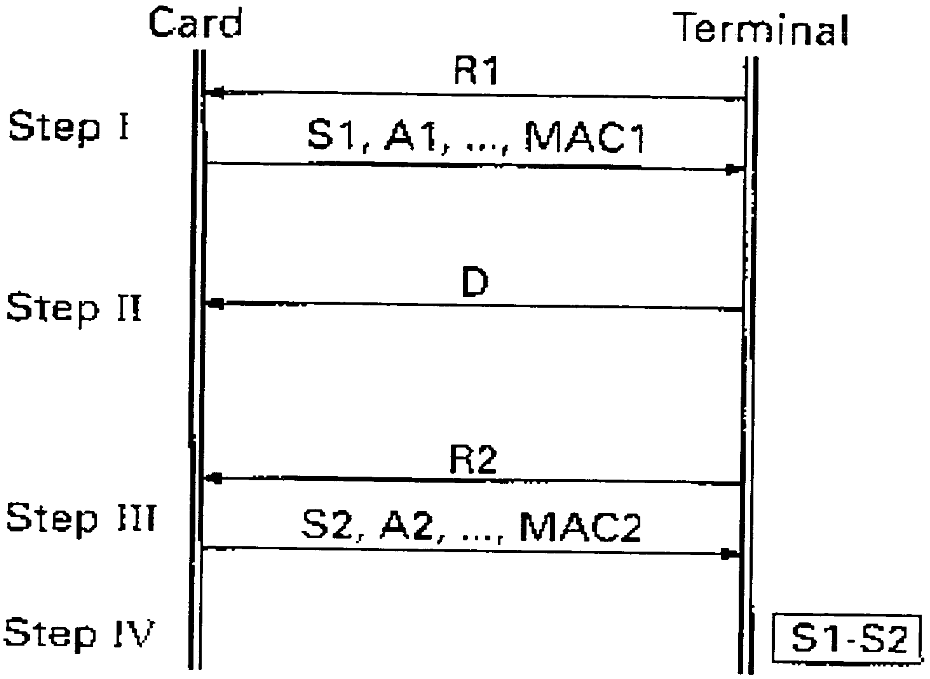
Card
Terminal
R1
Step I
S1, A1, ..., MAC1
D
Step II
R2
Step III
S2, A2, ..., MAC2
Step IV
S1-S2

Fig.2

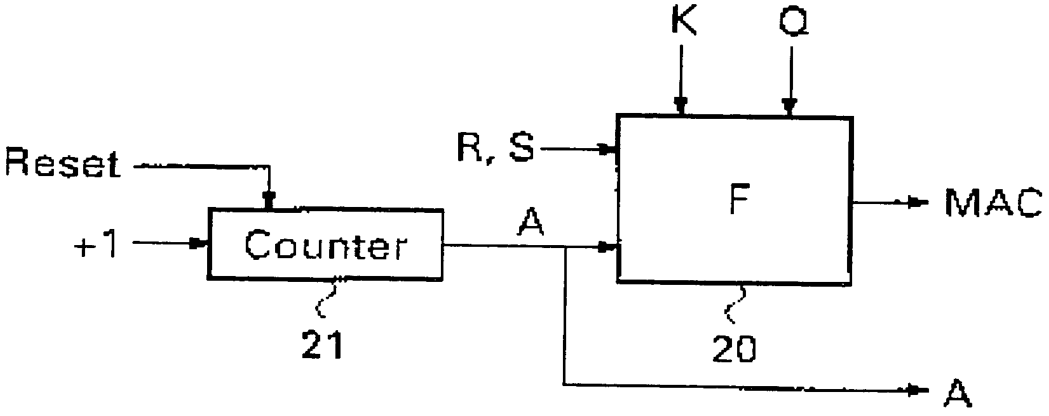
K
Q
R, S
Reset
F
MAC
+1
Counter
A
21
20
A

Fig.3

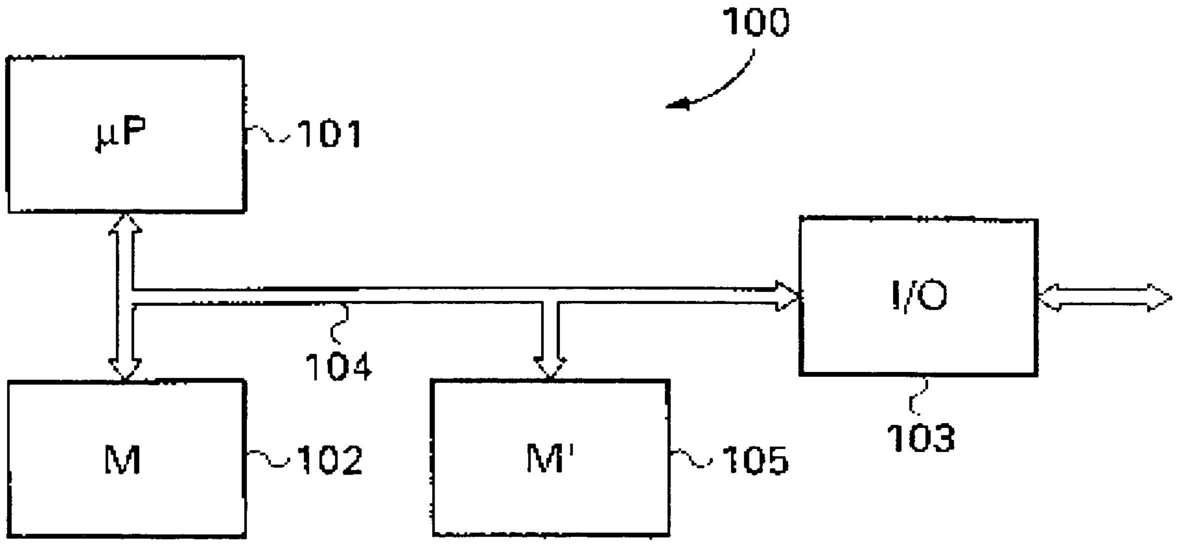

Fig. 4